(12) UK Patent Application (19) GB (11) 2 266 794 (13) A

(43) Date of A publication 10.11.1993

(21) Application No 9209539.7

(22) Date of filing 01.05.1992

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(51) INT CL[5]
G05F 1/12, G06K 19/067

(52) UK CL (Edition L)
G3U UEA U212 U215
U1S S2271

(56) Documents cited
US 4924171 A US 4797541 A

(58) Field of search
UK CL (Edition K) G3U UAX UEA
INT CL[5] G05F 1/12, G06K 7/08 19/06
Online databases: W P I

(54) Inductively powered token and reader unit

(57) A unit (10) for reading an inductively powered token, such as a tag, keyfob or credit card, has a reader coil (12) producing a field to power the token. The amplitude (Vcp) of the reader coil waveform, which depends on the presence of a token, is sensed by a circuit (16, 17, 18) and controls the voltage (Vcc) applied to the coil (12) to ensure a constant voltage on the token irrespective of where it is placed in the reader coil field. Regulation is in accordance with the equation

$$Vcc = m\,(Vcp + {}^{c}/_{m})$$

where c and m are constants.

A reference voltage (Vref) represents the constant value ${}^{c}/_{m}$. Resistors (30, 31) form the sum of Vcp and ${}^{c}/_{m}$ which is passed through an operational amplifier (33) having a negative feed back loop with resistors (34, 35) to give a gain of m. The working height of the token is extended whilst simultaneously widening design tolerances.

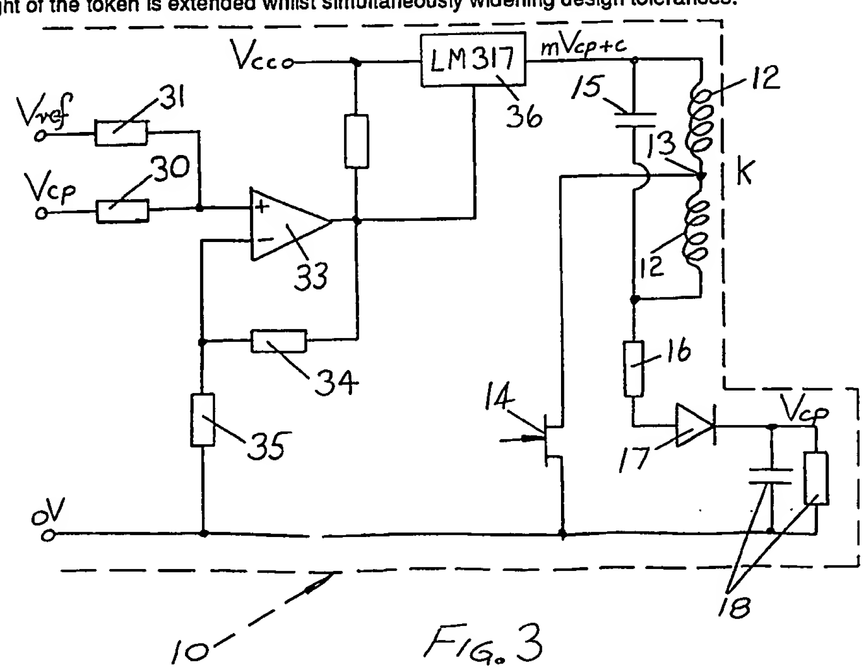

FIG. 3

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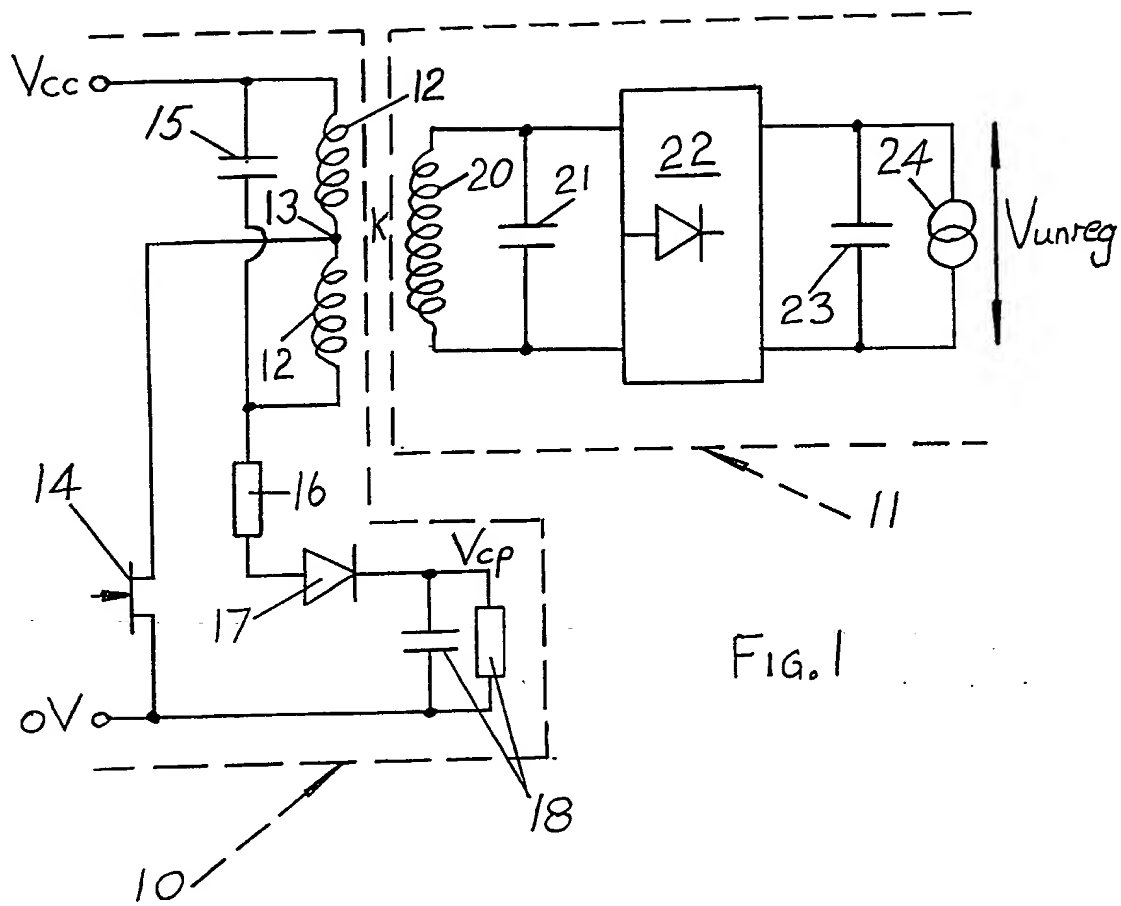
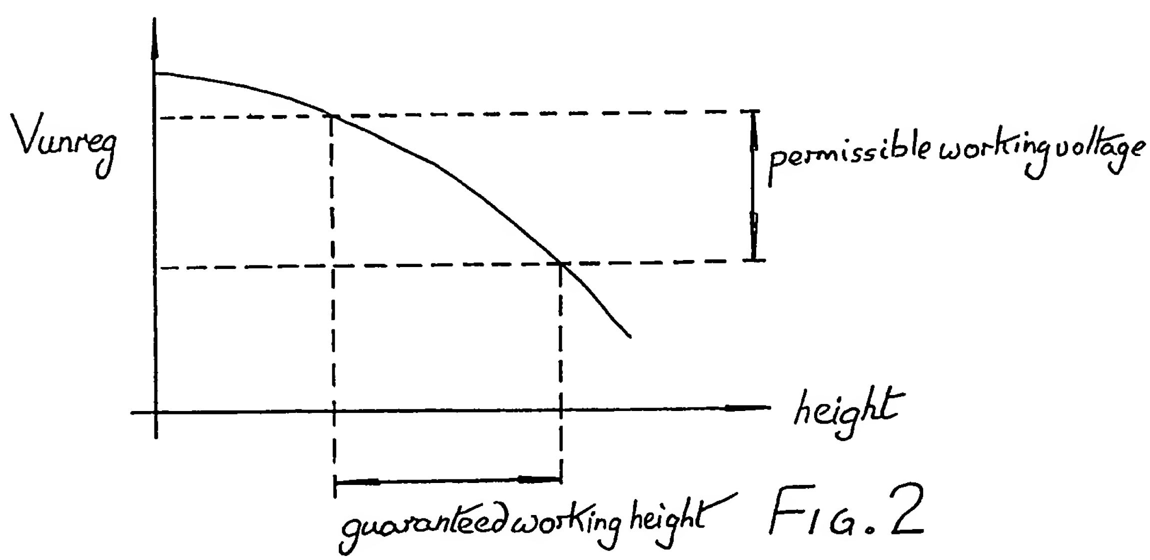


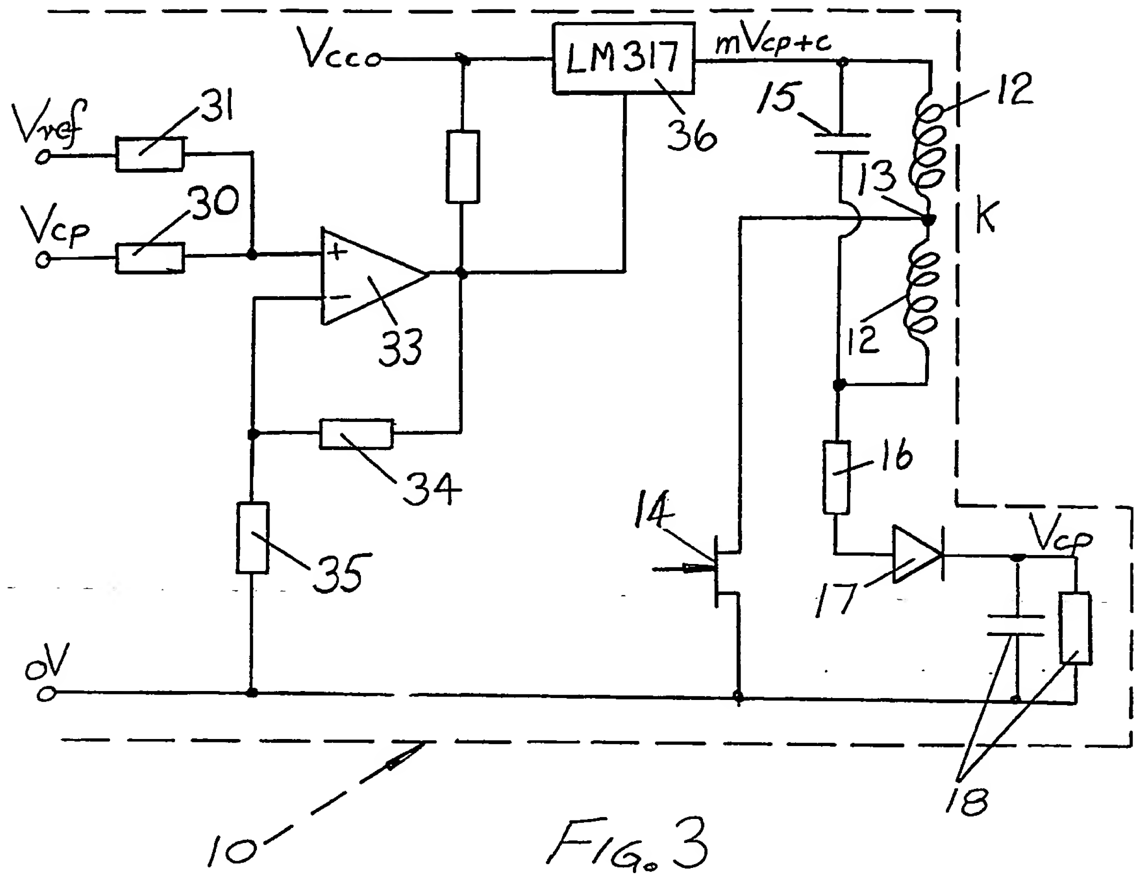
Vcc
15
12
13
K
20
21
22
24
Vunreg
12
23
11
14
16
Vcp
17
oV
18
10

FIG. 1



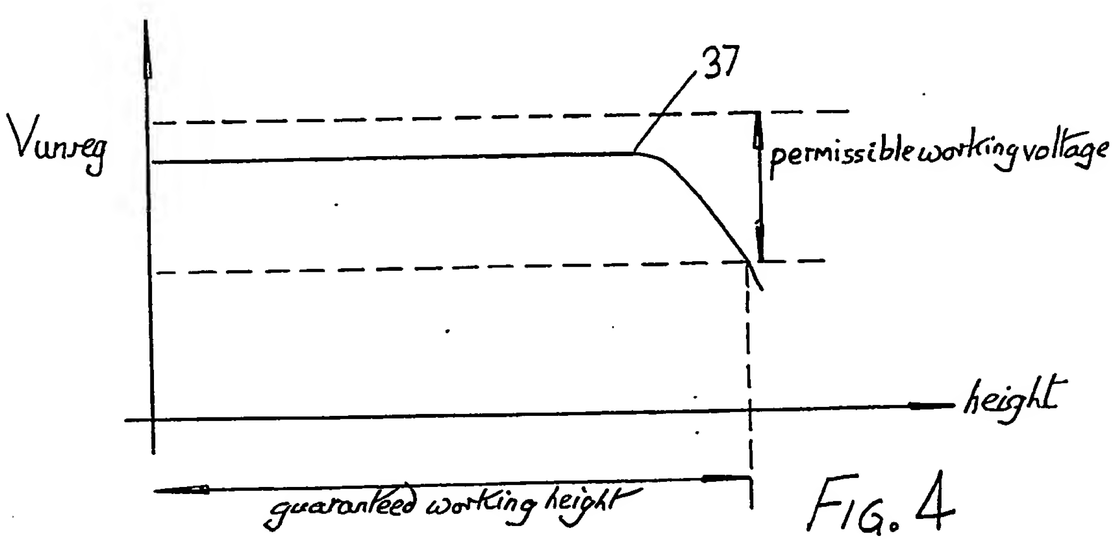
Vunreg
permissible working voltage
height
guaranteed working height

FIG. 2



Vcc
LM317
mVcp+c
Vref
31
30
Vcp
36
15
12
13
K
33
12
34
16
14
35
17
Vcp
0V
18
10

FIG. 3



37
Vunreg
permissible working voltage
height
guaranteed working height

FIG. 4

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DATA SYSTEM, READER UNIT FOR READING AN INDUCTIVELY POWERED TOKEN, AND SUCH TOKEN

The invention relates to a reader unit for reading an inductively powered token, a data system incorporating such reader unit and also to an inductively powered token for use with such reader unit or in such data system. The inductively powered token can take the form of a tag, a key fob, a credit card, or any other object containing information to be supplied to a reader unit. Such tokens usually comprise a token coil to receive magnetic flux from the reader unit, optionally a tuning capacitor to improve performance, means for rectifying the voltage induced in the token coil, and a voltage regulator to control the rectified voltage applied to the operative circuits of the token.

In an article by Mr. Tom Ivall published in Electronics & Wireless World, pages 577 - 579, the energisation of implanted nerve stimulators by electromagnetic induction is discussed. More particularly, it is stated that such implanted stimulators, and probably inductive links in other applications outside of medicine, should be operationally flexible in tolerating some uncertainty in the working distance between the energy

transmission coil and the subcutaneous receiver coil. More particularly it is recognised that variations in the working distance, and therefore coupling coefficient, between the two coils should not affect the amount of electromagnetic energy coupled into the receiver too drastically and reference is made to a "separation-insensitive link" designed by PEK Donaldson and the subject of UK Patent Application No. 8622274. The separation-insensitive link is a combination of self-oscillating series-resonant transmitter and series-resonant receiver, and relies on the energy transferred to the receiver being independent of the mutual induction coupling coefficient, k, over a useful range. This article teaches how a constant voltage can be developed in a subcutaneous tag over a wide range of coupling coefficients, subject to the two coils being overcoupled (coupling coefficient > critical coupling for the system) and that the carrier frequency is allowed to vary. Most data systems utilising inductively powered tokens rely on a stable carrier frequency and it would be undesirable to vary the carrier frequency as the position and orientation of the token varies, because the carrier frequency is also used as the basis of the clock for the token intelligence and memory. Accordingly the proposals in this article would limit the range of operation of an inductive token because of the need to vary the carrier

frequency.

US Patent 4797541 teaches how a reader unit can be arranged to provide a precise amount of power to an inductively powered token, by using a microprocessor and by measuring the performance of the reader coil circuit before the inductively powered token is placed near it.

It is an object of the present invention to provide a reader unit for reading an inductively powered token, such a token, and a data system utilising such reader unit and such token, in which an approximately constant voltage is maintained on the token irrespective of where it is placed within the R.F. field generated by the reader coil. More particularly, this invention is concerned with achieving this objective without any need to alter the carrier frequency and without any need to provide a microprocessor for calculating the currents and subsequently providing the correct amount.

According to the invention a reader unit, for reading an inductively powered token, includes a reader coil for producing a field to power the token, means for sensing the amplitude of the reader coil waveform, and a feedback circuit to regulate the voltage applied to the reader coil

as a direct function of the amplitude of the reader coil waveforms. In this manner the power supplied to the token coil is calculated by analogue means in real time, not just when the token is placed on or in the reader unit. Furthermore, this enables the token to be moved with respect to the reader coil which cannot be done utilising the teaching of US Patent 4797541.

A variable voltage regulator is preferably provided for varying the voltage applied to the reader coil, and the feedback circuit is arranged to control the variable voltage regulator. In this case the feedback circuit preferably includes circuit elements to control the variable voltage regulator at least approximately in accordance with the equation.

$$Vcc = mVcp + c$$

where: Vcc is the voltage applied to the reader coil,

Vcp is the amplitude of the reader coil waveform, and

m and n are constants

The circuit elements preferably include means for producing a reference voltage Vref to express the ratio of $^{c}/_{m}$, means for summing the reference voltage and the

amplitude of the reader coil waveform Vcp, and a negative feedback loop arranged to give a gain of m to the summation of Vref and Vcp. The means for sensing the amplitude of the reader coil waveform is preferably also arranged to detect from the reader coil waveform whether a token is inductively coupled with the reader coil.

According to another aspect of the invention a data system comprises a reader unit as taught by the present invention and a plurality of tokens, each token being provided with a token coil to receive magnetic flux from the reader coil and means for rectifying the voltage induced in the token coil. Preferably, the tokens are not provided with any means for regulating the rectified voltage, and the rectified voltage is maintained approximately constant by the regulation of the voltage applied to the reader coil.

According to a further aspect of the invention a token, for use with a reader unit in accordance with the invention, is provided with a token coil to receive magnetic flux, means for rectifying the voltage induced in the token coil, and is arranged to function on the unregulated voltage induced in the token coil.

In accordance with the invention, a constant voltage

is maintained on a token irrespective of where is it placed within the R.F. field generated by the reader coil. The position and orientation of the token coil, relative to the reader coil, affects the coupling coefficient K which is one of the parameters effecting the voltage induced on the token coil. The primary limitation to this concept is the maximum available power supply which will limit the maximum operative spacing between the token coil and the reader coil.

The invention will now be described with, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a circuit diagram of a known data system incorporating a reader unit and a token;

Figure 2 is a graph illustrating the range of guaranteed working height achieved with the arrangement illustrated in Figure 1;

Figure 3 illustrates the circuit of a reader unit in accordance with the present invention, and

Figure 4 is a graph illustrating the increased range

of guaranteed working height provided by a reader unit in accordance with the present invention.

With reference to Figure 1, a reader unit is indicated generally by arrow 10, and an inductively powered token, in the form of a smart card, by arrow 11.

The reader unit 10 has a direct current supply Vcc connected to a reader coil 12 which is tapped at 13 to provide a voltage amplification and is driven by a field effect transistor 14 in known manner. Typically the field effect transistor would be gated by a modulation signal to cause fluctuating currents to oscillate the reader coil 12. A tuning capacitor 15 may be positioned, as shown, to increase the efficiency of the reader coil 12 in known manner. A voltage signal Vcp is used to detect whenever the token 11 is inductively coupled with the reader coil 12, and is derived from the reader coil 12 through a high impedance resistor 16 which allows the reader coil waveform to be tapped without effecting it. A diode 17 is provided to rectify the reader coil waveform, and a filter 18 is used to smooth the reader coil waveform to provide an indication of the amplitude of the reader coil voltage. Vcp is used purely to detect whether the token 11 is in, or on, the reader unit 10, and typically is arranged to operate a

switch, or other decision component, to signal to the reader unit 10 whether or not a token 11 is in position.

The inductively powered token 11 has a token coil 20 for inductive coupling with the reader coil 12 at a coupling coefficient k. Optionally, a tuning capacitor 21 may be arranged in known manner to optimise the efficiency of the token 11. A rectifier circuit 22 is provided to produce an unregulated D.C. output which is applied, across a ripple smoothing capacitor 23, to a constant current regulator 24 of which the output is Vunreg. Any variation in the position between the token coil 20 and the reader coil 12 will alter the value of k and, as the regulator 24 provides a constant load, the value of Vunreg will alter accordingly as illustrated in Figure 2.

From Figure 2, it will be noted that Vunreg will vary with the height of the token coil 20 above the reader coil 12, that is the gap between the coils 12 and 20. For the token to operate satisfactorily, the applied potential must be between the predetermined limits illustrated in Figure 2 which, by extrapolation, determine the height, or effective gap, at which the token is guaranteed to work.

In Figure 3, part of the circuit for the reader unit

10 is identical to that already described with reference to Figure 1 and, accordingly, the same reference numerals have been utilised to indicate equivalant components which will not be described any further.

The circuit illustrated in Figure 3 is designed to take account of the realisation that, if Vunreg is to be held substantially constant, then:-

$$Vcc = mVcp + c$$

where: m and c are constants

It is therefore possible to maintain Vunreg substantially constant by reading Vcp and applying the above equation to set Vcc. This can best be envisaged by rewriting the above equation as follows:-

$$Vcc = m(Vcp + {}^{c}/_{m})$$

In the circuit of Figure 3, it will be noted that Vcp is used as an analogue signal feeding back to a resistor 30 which is arranged in parallel to a resistor 31 to which a reference voltage Vref is applied. It is arranged for Vref to represent the constant value of ${}^{c}/_{m}$ and to be set either

from a band gap reference or from Vcc via a potential divider.

The resistors 30 and 31 are chosen to sum Vcp and $^c/_m$. An operational amplifier 33 is provided with a negative feed back loop containing resistors 34 and 35 to give a gain of m which, of course, is set by the ratio of the resistors 34 and 35.

The output from the operational amplifier 33 is accordingly a measure of m(Vcp + $^c/_m$) which is otherwise mVcp + c and is applied to a variable voltage regulator 36 thereby modulating Vcc according to the equation Vcc = mVcp + c.

Figure 4 is a typical graph of Vunreg for a token coil 20 inductively coupled to the circuit of Figure 3. It will be noted that Vunreg is constant over a much wider range of working height (that is effective gap) and only starts to fall off at 37 due to the limitations of Vcc.

Because the reader unit 10 taught by Figure 3 effectively maintains a constant voltage within the token 11 irrespective of the working gap between the reader coil 12 and the token coil 20 (within the limitation of the Vcc),

the structure of the token 11 can be simplified by omitting any means for regulating the rectified voltage from the rectifier circuit 22.

The invention provides a number of advantages over prior arrangements. Of particular importance, the design tolerances on the card can be widened, therefor making the card easier to manufacture and consequently cheaper. The reason design tolerances could be widened is that inductively powered tokens will only work properly over a predetermined voltage range. The lowest working voltage is set by the technology used for the rest of the circuitry on the token after the rectifier 22 and regulator 24, for instance, if the rest of the circuit requires 5V, then the lowest working voltage might be 6V to guarantee that 5V is always generated by the regulator 24. On the other hand, the highest working voltage is set by the technology, geometry, size and power dissipation requirements, that is the highest permissible working voltage which might typically be 12V. One could possibly use higher working voltages but there would then be a risk of the token being damaged.

Accordingly, each token might have an ideal working range of between 6V to 12V, although it could be different.

When one is considering the production of thousands or millions of tokens potentially working on a reader unit, it is necessary to take account of the tolerances in the token circuit design, for instance token coil resistance tolerance, tuning capacitor tolerance, current consumption tolerance, and how the token is manufactured. All of these design parameters affect the voltage generated on a token. For instance, for all tokens placed at the same position and orientation in a field generated by a reader coil, one might see 8.75V ± 0.75V, that is a range from 8V to 9.5V. Therefore it would only be possible to guarantee that all tokens would work on a reader unit by stating the positions over which they have voltage range varied from 6.75V to 11.25V for example.

Therefore a "constant voltage" on the token of, say 9V, would allow tolerances in token design to be widened such that the working voltage tolerance was a ± 3V; that is without exceeding a maximum voltage of 12V.

Another advantage provided by the present invention is that less power is dissipated in the token which might previously have had to handle up to 12V whereas the maximum it would now encounter would be 9V. There is also less power dissipation in the reader unit because, as the token

coil gets closer to the reader coil, the voltage in the reader unit is reduced to stop the voltage rising on the token, thereby reducing the power consumption of the reader unit.

A further advantage is that the height/position range for the token would be extended because its affect on the working voltage is no longer the limiting factor.

Other advantages have been discussed in the specification, but it should be noted that the manufacturing cost of the token can also be reduced by omitting the previously necessary regulator.

CLAIMS

1. A reader unit, for reading an inductively powered token, including a reader coil for producing a field to power the token, means for sensing the amplitude of the reader coil waveform, and a feedback circuit to regulate the voltage applied to the reader coil as a direct function of the amplitude of the reader coil waveform.

2. A reader unit, according to Claim 1, in which a variable voltage regulator is provided for varying the voltage applied to the reader coil, and the feedback circuit is arranged to control the variable voltage regulator.

3. A reader unit, according to Claim 2, in which the feedback circuit includes circuit elements to control the variable voltage regulator at least approximately in accordance with the equation.

$$Vcc = mVcp + c$$

where: Vcc is the voltage applied to the reader coil,

Vcp is the amplitude of the reader coil waveform, and

m and n are constants

4. A reader unit, according to Claim 3, in which the circuit elements include means for producing a reference voltage Vref to express the ratio of $^{c}/_{m}$, means for summing the reference voltage and the amplitude of the reader coil waveform Vcp, and a negative feedback loop arranged to give a gain of m to the summation of Vref and Vcp.

5. A reader unit according to any preceding claim, in which the means for sensing the amplitude of the reader coil waveform is also arranged to detect from the reader coil waveform whether a token is inductively coupled with the reader coil.

6. A reader unit substantially as described herein with reference to the accompanying drawings.

7. A data system comprising a reader unit according to any preceding claim and a plurality of tokens, each token being provided with a token coil to receive magnetic flux from the reader coil and means for rectifying the voltage induced in the token coil.

8. A data system, according to Claim 7 in which the tokens are not provided with any means for regulating the

rectified voltage, and the rectified voltage is maintained approximately constant by the regulation of the voltage applied to the reader coil.

9. A data system substantially as described herein with reference to the accompanying drawings.

10. A token, for use with a reader unit in accordance with any of Claims 1 to 6, provided with a token coil to receive magnetic flux, means for rectifying the voltage induced in the token coil, and arranged to function on the unregulated voltage induced in the token coil.

11. A token substantially as described herein with reference to the accompanying drawings.

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Patents Act 1977
xaminer's report to the Comptroller under Section 17 (The Search Report)

Application number
9209539.7

Relevant Technical fields

(i) UK Cl (Edition K) G3U (UAX, UEA)

(ii) Int Cl (Edition 5) G05F 1/12
G06K 7/08 19/06

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Search Examiner

D C BRUNT

Date of Search

28 JULY 1992

Documents considered relevant following a search in respect of claims 1-11

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	US 4924171 A (BABA) - see Figure 6	1,2,7,10
X	US 4797541 A (BILLINGS) - see Column 2 lines 16-37	1,2,7,8, 10

SF2(p) sw - doc99\fil000251

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

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